



## Direct Coupling From WGM Resonator Disks to Photodetectors

NASA's Jet Propulsion Laboratory, Pasadena, California

Output coupling of light from a whispering-gallery-mode (WGM) optical resonator directly to a photodetector has recently been demonstrated. By "directly" is meant that the coupling is effected without use of intervening optical components. Heretofore, coupling of light into and out of WGM resonators has been a complex affair involving the use of such optical components as diamond or glass prisms, optical fibers, coated collimators, and/or fiber tapers. Alignment of these components is time-consuming and expensive.

To effect direct coupling, one simply mounts a photodetector in direct me-

chanical contact with a spacer that is, in turn, in direct mechanical contact with a WGM resonator disk. The spacer must have a specified thickness (typically of the order of a wavelength) and an index of refraction lower, by an adequate margin, than the indices of refraction of the photodetector and the WGM resonator disk. This mechanically simple approach makes it possible to obtain an optimum compromise between maximizing optical coupling and maximizing the resonance quality factor ( $Q$ ).

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*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

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## Using Digital Radiography To Image Liquid Nitrogen in Voids

X-ray motion pictures show draining and filling caused by cryopumping.

Marshall Space Flight Center, Alabama

Digital radiography by use of (1) a field-portable x-ray tube that emits low-energy x-rays and (2) an electronic imaging x-ray detector has been found to be an effective technique for detecting liquid nitrogen inside voids in thermal-insulation panels. The technique was conceived as a means of investigating cryopumping (including cryoingestion) as a potential cause of loss of thermal insulation foam from space-shuttle external fuel tanks. The technique could just as well be used to investigate cryopumping and cryoingestion in other settings.

In images formed by use of low-energy x-rays, one can clearly distinguish between voids filled with liquid nitrogen and those filled with gaseous nitrogen or other gases. Conventional film radiography is of some value, but yields only non-real-time still images that do not show time dependences of levels of liquids in voids. In contrast, the present digital radiographic technique yields a succession of images in real time at a rate of about 10 frames per second. The digitized images can be

saved for subsequent analysis to extract data on time dependencies of levels of liquids and, hence, of flow paths and rates of filling and draining. The succession of images also amounts to a real-time motion picture that can be used as a guide to adjustment of test conditions.

*This work was done by Dwight Cox and Elana Blevins of Lockheed Martin Corp. for Marshall Space Flight Center. Further information is contained in a TSP (see page 1). MFS-32443-1*

## Multiple-Parameter, Low-False-Alarm Fire-Detection Systems

Compact, low-power systems detect fires reliably.

John H. Glenn Research Center, Cleveland, Ohio

Fire-detection systems incorporating multiple sensors that measure multiple parameters are being developed for use in storage depots, cargo bays of ships and aircraft, and other locations not amenable to frequent, direct visual inspection. These systems are intended to

improve upon conventional smoke detectors, now used in such locations, that reliably detect fires but also frequently generate false alarms: for example, conventional smoke detectors based on the blockage of light by smoke particles are also affected by dust particles and water

droplets and, thus, are often susceptible to false alarms. In contrast, by utilizing multiple parameters associated with fires, i.e. not only obscuration by smoke particles but also concentrations of multiple chemical species that are commonly generated in combustion, false

alarms can be significantly decreased while still detecting fires as reliably as older smoke-detector systems do.

The present development includes fabrication of sensors that have, variously, micrometer- or nanometer-sized features so that such multiple sensors can be integrated into arrays that have sizes, weights, and power demands smaller than those of older macroscopic sensors. The sensors include resistors, electrochemical cells, and Schottky diodes that exhibit different sensitivities to the various airborne chemicals of interest. In a system of this type, the sensor readings are digitized and processed by advanced signal-processing hardware and software to extract such chemical indications of fires as abnormally high concentrations of CO and CO<sub>2</sub>, possibly in combination with H<sub>2</sub>

and/or hydrocarbons. The system also includes a microelectromechanical systems (MEMS)-based particle detector and classifier device to increase the reliability of measurements of chemical species and particulates.

In parallel research, software for modeling the evolution of a fire within an aircraft cargo bay has been developed. The model implemented in the software can describe the concentrations of chemical species and of particulate matter as functions of time.

A system of the present developmental type and a conventional fire detector were tested under both fire and false-alarm conditions in a Federal Aviation Administration cargo-compartment-testing facility. Both systems consistently detected fires. However, the

conventional fire detector consistently generated false alarms, whereas the developmental system did not generate any false alarms.

*This work was done by Gary W. Hunter, Paul Greensburg, Robert McKnight, and Jennifer C. Xu of Glenn Research Center; C. C. Liu of Case Western Reserve University; Prabir Dutta of Ohio State University; Darby Makel of Makel Engineering, Inc.; D. Blake of the Federal Aviation Administration; and Jill Sue-Antillio of Sandia National Laboratories. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18067-1.*

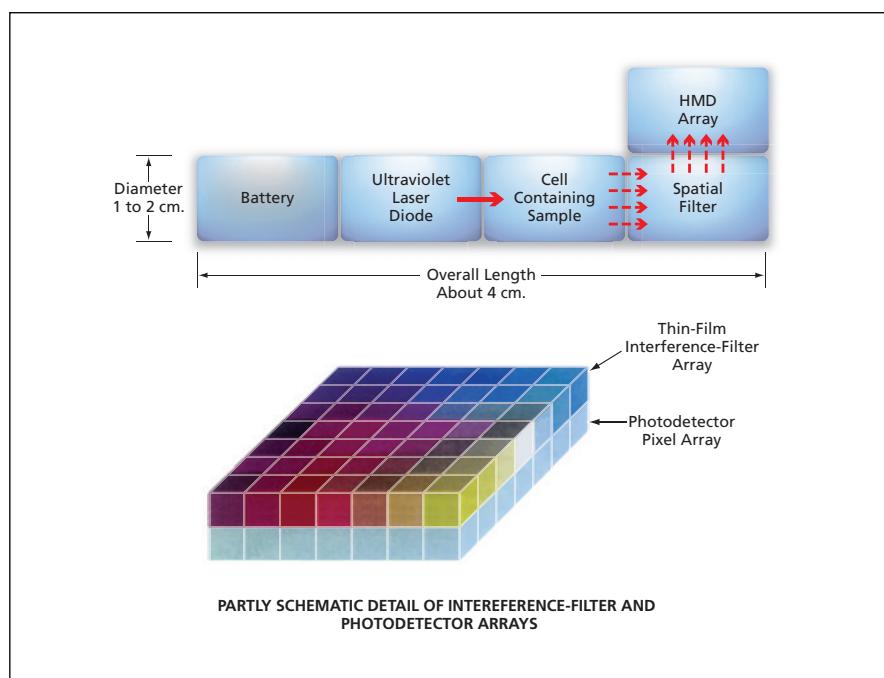
## Mosaic-Detector-Based Fluorescence Spectral Imager

This portable instrument would perform comparably to larger laboratory instruments.

NASA's Jet Propulsion Laboratory, Pasadena, California

A battery-powered, pen-sized, portable instrument for measuring molecular fluorescence spectra of chemical and biological samples in the field has been proposed. Molecular fluorescence spectroscopy is among the techniques used most frequently in laboratories to analyze compositions of chemical and biological samples. Heretofore, it has been possible to measure fluorescence spectra of molecular species at relative concentrations as low as parts per billion (ppb), with a few nm spectral resolution. The proposed instrument would include a planar array (mosaic) of detectors, onto which a fluorescence spectrum would be spatially mapped. Unlike in the larger laboratory-type molecular fluorescence spectrometers, mapping of wavelengths to spatial positions would be accomplished without use of relatively bulky optical parts. The proposed instrument is expected to be sensitive enough to enable measurement of spectra of chemical species at relative concentrations <1 ppb, with spectral resolution that could be tailored by design to be comparable to a laboratory molecular fluorescence spectrometer.

The proposed instrument (see figure) would include a button-cell battery and a laser diode, which would generate the monochromatic ultraviolet light needed to excite fluorescence in a sample. The sample would be held in a cell bounded



This Pen-Sized Instrument would measure the fluorescence spectrum of a sample with high resolution and sensitivity.

by far-ultraviolet-transparent quartz or optical glass.

The detector array would be, more specifically, a complementary metal oxide/semiconductor or charge-coupled-device imaging photodetector array, the photodetectors of which would be tailored to respond to light in

the wavelength range of the fluorescence spectrum to be measured. The light-input face of the photodetector array would be covered with a matching checkerboard array of multilayer thin-film interference filters, such that each pixel in the array would be sensitive only to light in a spectral band narrow